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University and Business Relations: Connecting the Knowledge Economy

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Abstract It is commonplace to say that the modern economy is knowledge based but a moment's reflection points to the vacuity of this notion. For all economies are knowledge based and could not be otherwise. The question is rather how is one kind of knowledge based economy to be distinguished from another? This essay proposes that the answer may lie in three directions: (1) in terms of the variety of knowledge that is engaged; (2) in terms of the processes by which the production of knowledge is organised, and its corollary the resources devoted to knowledge production and dissemination; and, (3) in terms of the purposes to which knowledge is put. In respect of each of these dimensions, the rise of the modern university as a custodian of knowledge in Western economy and society has been of central importance; but universities are not alone in this role, a wide range of other agencies, private firms, public research laboratories for instance play an important role in defining a knowledge economy and have done so increasingly since the turn of the nineteenth century—a first indication of the systemic dimensions of a modern knowledge economy.

Keywords Universities, businesses · Interactions · Knowledge economy

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Introduction[1]

The old question "How is wealth created from knowledge?" captures with great force and clarity one of the most important problems in any economy, but it subsumes a far more particular and very modern instantiation, a simpler and more direct question, "How should universities interact with business in the promotion of economic progress?" Like many seemingly simple questions, they preclude any simple answers, yet it turns out that by focusing on the role of universities in the innovation process we can identify some of the deeper complexities of our knowledge based economies. In so doing, we may better understand the design of university-business relationships in pursuit of economic progress and provide surer guidance for policy initiatives in this area. The subject is certainly topical, witness the recently published review of the Australian innovation system (Cutler et al. 2008), while universities worldwide are being asked to be "useful" and to account for their utility to the degree that it seems to some that the implicit contract between universities and society is being rewritten. If so, it ought to be rewritten in a way that damages neither the universities nor their supporting society, and this is not an easy matter to untangle.[2]

The utilitarian theme is further sharpened by the fact that universities are perceived increasingly not only as sources of knowledgeable students and potentially profitable ideas for others to exploit, but as direct contributors to national and regional economic development through the formation of spin-off companies and the exploitation of technology licensing arrangements.[3] The invention of ideas and novel theoretical understandings has always been central to university life and the invention of useful devices has often followed as a natural byproduct, especially in disciplines such as engineering and medicine that are defined by pressing practical problems. But the charge that universities should become direct vehicles of exploitation is new and problematic. Their ability to do so

[1] The origin of this essay lies in the invitation to give the Haydn Williams lecture at Curtin University of Technology in October 2008. Professor Williams was the Inaugural Director of the Western Australian Institute of Technology, the parent of today's Curtin University of Technology. He had a deep interest in the role of technological education in modern life, and so I thought it appropriate to focus my lecture on a question that I hoped he would have approved of, namely the role of business and university relations in a modern advanced economy. It is a great honour to have held a Haydn Williams Fellowship and I register my deep appreciation to Curtin University for entrusting me with the responsibilities associated with it. My warm thanks too to Professor Harry Bloch and his colleagues in Curtin Business School for their never failing hospitality, intellectual as well as social. This essay draws on joint work with Paul David (David and Metcalfe 2008) arising from our membership of the Expert Group on Knowledge for Growth within DG12 of the EU Commission. Any deficiencies in this paper are entirely of my making. Comments on successive drafts by Davide Consoli, Jacob Edler, Nic de Liso, Andy McMeekin and Richard Nelson were much appreciated. Some aspects of the paper were developed during a visit to the Centre for Advanced Study in Oslo in May 2008, to which organisation, and Professor Jan Fagerberg in particular, I express my gratitude for the excellent facilities they provided for itinerant scholars. The comments of two referees on the penultimate draft are gratefully acknowledged, even though I might not have done them justice in this final version.

[2] See Martin (2003) for a contemporary account of the changing social contract.

[3] Ashby (1974) puts it thus, "Now universities have become absolutely essential to the economy. Under the patronage of modern governments they are cultivated as intensive crops, heavily manured and expected to give a high yield essential to the nourishment of the state" (quoted from page 7).

depends on factors extraneous to the pursuit of understanding and the administration of scholarly activity, such as access to venture capital and a capability to manage exploitation in a professional fashion (Mowery and Sampat 2001, 2005). These of themselves are sufficient reason to revisit the connections between wealth creation and the development of human knowing.

A great deal has been written about the shifting balance of university-business relationships, the entrepreneurial university and the business oriented university, but here I propose to stand back and consider the problem from a more general perspective.[4] What possible frame of reference will help us understand with greater clarity how universities and business firms interact? The view I explore here is that the distinctive worlds of universities and businesses in a modern economy are coupled sub systems of a complex adaptive system, one which transcends national boundaries and is governed by principles of self organisation and adaptive evolution. These systems are restless and are characterised by the continuing development of new system components, new connections and shifting boundaries. It is within this context that we might usefully appraise the concerns of policymakers with the university-business nexus and pay careful attention to the multiple forms of valuable interaction between them, not all of which fall prey to ready forms of measurement.

The systemic view I explore is itself premised on three sets of ideas, in relation to the principle of the division of labour, the processes of knowledge accumulation, and the co-operative, systemic nature of the innovation process. Taken together, these ideas point to the powerful role that universities play in shaping the evolution of economic activity, and they have two important consequences. On the one hand, they justify the ongoing concern of policymakers with "adaptively improving" university-business relationships in relation to wealth creation. On the other hand, they also point to the deeper subtlety of the relations between firms and universities and their uneven nature, which suggests that suitable policies to enhance the transfer of university developed ideas into commercial practice must be crafted carefully if we are to avoid substantial long run costs to economic progress. Of course, I am conscious of great differences in the form of the university systems in different countries and even more that the connections between business and academy differ greatly across different fields of economic activity. These national and industry differences make generalisations difficult so the reader must bear this in mind in what follows.

To indicate at the outset the general nature of our discussion, it is premised on one of the most important distinctions in complex systems analysis, that between spontaneous and designed orders, the distinction made famous by Hayek in terms of cosmos and taxis (Hayek 1973). All human action that is social in nature is premised on organisation in some form but the possible kinds of organisation fall into two distinct families. Designed organisations such as firms and universities are constructed for an explicit purpose, and can be guided in their actions by individuals who comprehend the scale, structure processes and purpose that make

[4] See, for example, Agrawal (2001), Perkmann and Walsh (2007), Rothaermel et al. (2007), and Siegal et al. (2007) for surveys of a large and growing literature.

their organisations function. On the other side of the divide are spontaneous forms of organisation that have no central guiding authority and which are governed not by specific individuals but by generally accepted rules that have emerged over the course of time as the result of countless trial and error experiments. Market processes are the prime example of such spontaneous orders but we need to give equal attention to the instituted rules that shape the conduct of scientific and scholarly activity and the more general forms of spontaneous order that we refer to as social networks.[5] The boundary between the two organisational forms is certainly ill defined but the distinction is nonetheless pointing to a vitally important distinction between different ways in which the inconsistent plans of different individuals are reconciled. Moreover, a crucial feature of such spontaneous orders is their systemic breadth which takes them beyond the comprehension of any individual mind or group of minds, and the corollary that their development is entirely open and unpredictable in terms of specific details even when the general order forming rules are unchanged.

The Division of Labour and the Knowledge Economy

It is commonplace to say that the modern economy is knowledge based but a moment's reflection points to the vacuity of this notion; all economies are knowledge based and could not be otherwise. The pertinent question is rather the manner in which one kind of knowledge based economy is to be distinguished from any another. Here, three discriminators are relevant to our discussion: the varieties of knowledge that are generated within an economic system; the different processes by which the production of knowledge is organised (and their corollary, the resources devoted to knowledge production and dissemination); and the purposes to which different kinds of knowledge are applied. In respect of each of these dimensions, the rise of the modern university as a custodian of knowledge in Western economy and society has been of central importance. But universities are not alone in this role. A wide range of other agencies, private firms, public and private research laboratories, and professional societies play an important role, and have done so increasingly since the turn of the nineteenth century, a first indication of the systemic dimensions of a modern knowledge economy.

The fundamental fact that distinguishes the modern knowledge economy is the elaborate and ever developing division of labour in the production and use of new knowledge. Not surprisingly, Adam Smith pointed the way in 1776 in the *Wealth of Nations*. Everyone knows of the division of labour in the pin making factory and the connection drawn with human and organisational specialisation and the growth of productivity, without perhaps realising that it implies a division of human knowing as well. Less well appreciated is the fact that Smith's principle applied much more widely. When he wrote about a third class of division of labour, over and above those within and between firms in the use and production of machinery and the

[5] Science is here to be treated broadly, not only knowledge of the natural world but of the human built world to technology and organisational knowledge in particular.

specialisation of task, he meant the division of labour in the production of knowledge for invention, reflecting the activities of those,

> "…philosophers and men of speculation, whose trade is not to do anything, but to observe everything; and who, upon that account, are often capable of combining together the powers of the most distant and dissimilar objects … Like every other employment too, it is subdivided into a great number of different branches, each of which affords occupation to a particular tribe or class of philosophers; and this subdivision of employment in philosophy, as well as in every other business, improves dexterity, and saves time. Each individual becomes more expert in his own particular branch, more work is done upon the whole, and the quantity of science is considerably increased by it" (Smith 1776, Cannan edition, p. 11).

There are three aspects of Smith's argument to highlight. First, he is drawing attention to the many different, incommensurable kinds of knowledge that contribute to progress in a modern economy, and to the implicitly different conditions under which they are produced—the men of speculation are not also the pin makers or the makers of machines. The second is that, as with any division of labour, the effect of specialisation is to greatly increase the efficacy of knowledge production processes but this comes at a price. Because each individual philosopher is more highly specialised and increasingly ignorant of other branches of knowledge, the question of how the knowledge of different philosophers is to be coordinated becomes of paramount importance. Just as the work of the different employees in the pin factory must be organised, that is to say coordinated, the same is true for the production of knowledge. Without coordination, there is fragmentation and lack of communication, a failure to spread understanding, a failure to benefit from the testimony of others who we do not know. In other words, the power of the division of labour as producer of knowledge depends on complementary arrangements for the communication and coordination of those efforts and their results, that is to say it requires the knowledge accumulation process to have the properties of a connected system.[6] The instituting of education is obviously one way to spread knowledge and correlate understanding, and Smith's principle is reflected in the organisation of any modern university with its ever changing curricula and patterns of disciplinary specialisation.

But there is a third idea contained in Smith's thesis, namely that the division of labour not only leads to a greater refinement and fragmentation of the different kinds of knowledge, but that it also offers rich possibilities for the combination of different kinds of knowledge from different disciplines. Elements of fluid dynamics, materials science, pharmacology and genetics, for example, may be combined to generate a new medical sub discipline, as they are in the field of cardiac stenting, a

[6] Nic de Liso has drawn my attention to the writing of Charles Babbage in respect of the complementarity of different kinds of knowledge arising from the division of labour. He wrote that "[I]t is impossible not to perceive that the arts and manufactures of the country are intimately connected with the progress of the severer sciences; and that, as we advance in the career of improvement, every step requires, for its success, that this connection should be rendered more intimate…" (Babbage 1835, p. 379).

phenomena which is repeated many times over in the innovation process. The search for connecting principles between different bodies of knowing is very much part of Smith's understanding, and it matches naturally with the idea of innovation as a transdisciplinary process that must be organised by some means to combine knowledge of different kinds from different sources. This inherent richness of the epistemic landscape has a powerful implication for it means that knowledge can grow combinatorially fast, that is to say, faster than exponentially—no wonder scholars talk of a knowledge explosion when knowledge is increasing faster than our ability to exploit it.

Just as the kinds of knowledge are highly differentiated so are its producers. In medieval times, indeed in Smith's time, the site of production in workshop and factory was also the site where problems were solved, skills acquired and knowledge accumulated. It was in medieval workshops, for example, that the rudiments of mechanics, of the relation between circular and linear motion were first posed and solved.[7] What marks the development of the modern knowledge economy is that an important component of knowledge production gradually became separated from the day to day production of goods and services; it moved "offline", as it were, into specialised organisations, technical institutes and universities. This process accelerated from the eighteenth century onwards, and ultimately its consequences fell as a significant burden on the taxpayer in the early twentieth century, when states took increasing responsibility for the funding of research and the support of higher education. It also moved offline in the R&D departments of larger corporations that grew rapidly in number and scale from the early days of the twentieth century. In both cases a new context for the exploration of the unknown was created, a context that permitted vicarious exploration of the natural and human built worlds insulated from the demands of the immediate economy and society. This instituting of independent thought and discovery is perhaps one of the most powerful innovations in organisation that define a modern knowledge economy, as Whitehead famously expressed the point; it is coincident with the invention of the method of invention.

The economic and social effects of this developing division of labour have been profound, precisely because the rules of capitalist organisation encourage firms to feed off new knowledge and to translate ideas into profitable innovations and, in so doing, to continually transform our economic and social arrangements. Modern capitalism is a restless system within a broadly stable set of fundamental rules of organisation, but it is restless because human knowing is restless. It is this dynamic connection between the growth of knowledge and the transformation of economic life that Smith captured in his famous dictum—that the growth of the division of labour depends on the extension of the market which, in turn, is dependent on the growth of the division of labour, a feedback loop of the most potent kind.[8]

[7] See in particular, White (1962).

[8] As Young (1928) clearly understood in one of the most important papers on the economic power of the division of labour. Young was building on foundations laid by Marshall (1919, 1920), and, no doubt, both were aware of the profound developments in the division of labour associated with the principle of interchangeable parts and the complementary development of specialised machinery that characterised the then modern industries of sewing machine, bicycle and automobile manufacture.

Consequently, economic development and the development of knowledge are mutually reinforcing, connected by powerful feedback loops that constitute the most important branch of increasing returns that we know of. We are rich because we are collectively smart, but our material richness also requires that we are individually ignorant of all but a narrow area of expertise, the flip side of the division of labour.

What Smith failed to develop was the idea that knowledge does not flow freely from one individual to another, and to understand why requires that we pay some attention to the differences between information and knowledge. Only individuals can be said to have knowledge, for knowledge is an internal state of mind and what is known depends on perceptions, introspection, memory and inference, in short, individual and differentiated experience allied with reason and imagination (Audi 1998). These internal processes, by which we come to know as individuals, are greatly augmented by external social processes that permit exchanges of information in many forms. However, communicated information is not knowledge; it is a representation of knowledge which is not at all the same thing, as any university teacher and examiner knows only to well. Since cooperative action depends on the generation of understanding in common the role of communication processes is to correlate understanding to the degree that is necessary to coordinate behaviours at many different levels (Metcalfe and Ramlogan 2005). Some understandings are necessarily very general (the rules of the road) but the vast majority are local and highly specific to the performance of limited tasks within the relevant levels and kinds of organisation. The consequence of the division of labour is thus profound, in that it means that each individual is reliant for their daily functioning on the knowledge and the communicated testimony of others, the majority of whom will be unknown to him or her. The point I want to emphasise is that this extended reliance upon the testimony of others is one of the key factors in understanding capitalism and science as distinctive, knowledge-based spontaneous orders, and is thus of direct bearing on any understanding of university-business relations.

If information flow is to convey personal knowledge with sufficient accuracy to achieve commonality of understanding, then there must be common standards of communication, of language and other forms of symbolic representation, and agreed standards for the justification of that which can be said to be known. Otherwise private knowledge cannot develop into collective understanding. As Nelson puts it, there must be ‘social technologies’ to make testimony possible (Nelson and Sampat 2001; Nelson 2005). These correlating processes require explicit organisation and are a problem in information technology broadly defined. From the book to the internet,—from Gutenberg to Gates, if you will allow—a triad of technologies has developed involving means to substitute for face to face communication, means to store information in durable forms over time so that future generations can benefit from present discoveries, and means to manipulate information in ever more productive ways. The effects have been profound, not least on patterns of employment as mental labour has been progressively automated and the immediate flow of information to which we have access is cheapened to a remarkable degree. The telephone operator and the “exchange”, the bank clerk and the “ledger” are relics of the very recent past in today’s modern knowledge economy. Even more fundamentally, deeper communication possibilities greatly increase the possibilities for the combination of different kinds of knowledge, and innovation is a problem in combining different kinds of knowledge, it is a problem typically dependent upon a distributed sense of knowing.

Order and Transformation

There is another consequence of Smith's division of labour perspective to which we must attend. It is a commonplace to point to important differences between the worlds of business and the academy, and these differences are real as we shall see below. However, they are very much related to the particular designed organisational forms that we call firms and universities, and it is these differences in organisational design that shape the kinds of spontaneous orders that can emerge from their interaction. But this differentiating of organisational form and function is too easily overdone and masks what for our purposes is far more important, namely the remarkable parallels between the organisation and functioning of the market economy and of science. When we turn to problems of the different frameworks in which they operate, we find a far greater sense of commonality in terms of the general rules that lead to order formation even though the results produced are quite incommensurable. Our understanding of these parallels owes a great deal to Hayek's (1973) concept of spontaneous order and to Polanyi's (1962) concept of a republic of science. By an order is meant a pattern or structure of interactions that shape the outcomes of individual action, and the specifics of any particular order depend on the general instituting rules of the game that adjust the efforts of countless individuals in such a way that each one adapts to the results achieved by many others often unknown to him or her. In the economy, the patterns relate to the disposition and utilisation of resources contingent on a prevailing distribution of individual knowledge. In science, the patterns relate to the allocation of investigative effort again contingent upon the prevailing distribution of human knowing. In the one, the patterns are the outcome of the market process, in the other, they are product of the instituted rules of the scientific game, and, in each case, the pattern is rendered possible by flows of information that serve to correlate individual understandings to the requisite degree. In neither case is it true that the pattern is the result of a centrally imposed design, and in neither case are the future states of the respective orders predictable. The results of present action are from the wider perspective, unexpected, unpremeditated and emergent in the sense that they are not predictable in their entirety by any one mind. To say this is simply to acknowledge that future states of knowing are by definition unpredictable and that the economy and science are knowledge based systems. Economy and science each depend upon rule based incentive systems to achieve coordination and pattern formation, one in terms of income generation and the price mechanism, the other in terms of scientific status and authority achieved through publication of results. In both cases the rewards for effort are unevenly distributed—the wealthy business man has his twin in the authoritative scientist. All of this is, I imagine, common ground, but what is less well recognised is that the economy and science are not only self organising systems, they are also self transforming systems and there is a great deal of interdependence in the manner of their respective self transformations.

Their spontaneous orders are premised upon instituted, specific and durable sets of general rules, rules that are impervious to the specifics of any prevailing order. These rules have a double function: they serve to correlate the various degrees of understanding that permit co-operation and coordination of individual efforts; and, they stimulate challenges to that order in the form of novelties, innovations in the economy and new ideas within science. This premium on questioning the status quo has the effect that the respective orders are always changing from within: a delicate balance is drawn between the stability of order and conformism, and the instability caused by idiosyncratic, non-conformist behaviour. If economy and science were not open to invasion by novelty, then no progress could be made, they would be stationary, dead systems. Moreover, the manner of the respective processes of self transformation is evolutionary in the sense that it is driven by the unexpected emergence of novelty and by the subsequent adaptation of the prevailing order to the challenges immanent in that novelty. These are naturally variation cum selection processes. Thus, what the respective instituted frames have in common is twofold: they facilitate the emergence of coherent patterns of order and they self transform those orders; in the one case, in terms of the search for superior profitability, in the other, in terms of the search for professional status. This dual function of the two instituted frames is quite remarkable and is at the root of the ever developing structures of science and the economy. Here lies the commonality of role that we assign to the business entrepreneur and the creative scientist. For the chief characteristic of enterprise, in science as in economic life, is to de-correlate the pattern of private knowledge that sustains the prevailing order, to sow doubt where previously there was understanding in common. Hence, the emphasis on novelty, on challenging existing practices and understandings that is typical of Schumpeter's radical entrepreneur and typical of Kuhn's notion of the paradigm breaking scientist. Thus, entrepreneurs, like scientists, share much of the information flow of their fellow citizens but they interpret it in novel ways: they claim to know differently from others, they imagine that their respective worlds can be rendered different, and through their diverse imaginings they challenge the correlated understanding that others possess. The successful among them generate new patterns of understanding and, in so doing, induce sequences of imitative followers who complete the process of market adaptation or the restructuring of a particular body of science.[9] That their respective instituted rules constitute frameworks of adaptation to the possibilities hidden in novelty is central to any understanding of the close connection between enterprise and progress. It is the adaptive, open properties of markets and the institutions of science that are from our viewpoint their most remarkable feature.

Thus, Adam Smith's principle of order formation based on a division of labour becomes in the hands of Hayek and Polanyi a dynamic principle to govern the accumulation of knowledge and to be the foundation of economic progress. Science and the economy are, as Hayek expressed it, systems to ensure "The interplay of

[9] I have developed this theme more fully in Metcalfe (2006).

many minds in which alone mind can grow".[10] For this reason they are restless systems which are open ended in their development, we simply do not know the specifics of the future worlds that will be generated by their instituted rules. They are also coupled systems; real resources generated in the economy are allocated to scientific endeavours, while the growth of knowledge opens up possibilities for innovations that change the allocation of resources. Moreover, the problems of the real economy become stimuli for the development of knowledge, even basic scientific and technological knowledge as Rosenberg (1990) and Stokes (1997) have demonstrated.

Having dwelt on the similarities in the instituted rules of the game in science and the economy, we must now confront the very real differences in the designed organisational forms that we call business firms and universities. Here, the idea that the division of labour leads us to recognise business firms and universities as very different kinds of knowledge generating and using organisations. They differ in the processes by which they are created, they differ in their longevity (Cambridge celebrated 800 years of existence in 2009, the University of Jena, a distinguished German technical university, celebrated its 450th anniversary in 2008, no modern company comes as close), and they differ in their purposes and operating rules, and in their modes of governance. Moreover, few firms, though there are a few, ever come to rival the size of universities, which are predominantly very large organisations. Not only are the differences in academic and business organisation and substance relevant here. Fundamental and long standing differences in the relation between universities and their nation states are also extremely important: most continental European universities are effectively part of the machinery of government and their academics are career civil servants, a model that could not contrast more strongly with the almost complete separation and autonomy of the Anglo Saxon model of university-state relations in the UK, its former colonies, and the USA.[11]

At this point we can benefit from a little guidance from Joseph Schumpeter, the originator of the phrase "creative destruction" and of his distinction between invention and innovation. Invention is proof of concept and creation of a working device or artifact, and it is logically a quite different phenomenon from innovation. Innovation is the economic application of an invention, as he put it, it is "a new combination of resources" to produce an existing product more efficiently or a better product than those currently in production. Innovations require access to many more kinds of knowledge than do inventions, knowledge of markets and organisation in particular, and the absence of these complementary inputs is the

[10] Op cit, p. 49.

[11] That Australia, New Zealand, Hong Kong, South Africa followed a British but note not an Oxbridge model, is scarcely surprising. More interesting, perhaps because unexpected, is the influence of the French model on the newly independent Latin American countries in the nineteenth century and the influence of the German model on the USA, the universities of Chicago and Michigan as well as Johns Hopkins being notable examples. In neither case is the colonial link present. On this, see Shils and John (2004). Several of the early university presidents in the USA studied in Germany (C.W. Eliot at Harvard, for example) and the State of Michigan contained a large German speaking population which may have been a factor in that case. As Shils and Roberts point out, this is a matter of German influence, not the copying of a German template.

downfall of many a promising invention.[12] Inventions and innovations must pass very different tests of viability too. One asks of an invention does it work to achieve its intended effects. One asks of innovation is it profitable in the currently prevailing economic arrangements. These are quite different criteria for the establishment of reliable knowledge. In Schumpeter's scheme, there is no shortage of inventions to hinder economic progress (the combinatorial theme again); rather it is the flow of innovation that is the rate determining step in the process of economic development. What is invented is only a small part of what is potentially feasible, and an even smaller fraction of actual inventions ever acquire the stature of innovations and are translated into commercial ventures. Moreover, innovation and invention are activities with uncertain rewards, and there are many examples of innovations where the profitable application arrived from directions never expected by its originators. Serendipity has its way in innovation just as it does in invention.

The significance of this is that capitalism is so organised that for profit firms are the primary generators of innovations and business enterprise is the vehicle by which they do so. The modern firm is unique in that it, and it alone, is required to put together all the necessary knowledge required to innovate, knowledge that involves much more than R&D and much more than science and technology. It is the firm that must marshal the resources needed to render invention into innovation and it has strong incentives to do so. Schumpeterian competition, profits, and innovation based differentiation are at the heart of the business process but are quite foreign to the workings of the university where different forms of competition are in play. The modern university is by contrast a very powerful source of inventions, whether in theoretical understanding of natural or human built phenomena or empirical procedure or in new devices, it generates a pool of possibilities that might be the basis for innovation.

The consequence is that firms and universities operate with quite different rules for activities that require quite different timescales for their realisation.[13] Universities are part of open science, the pressing rule is to disclose and make findings available for critical testing by rival scientists, and indeed academic rewards and prizes are based on priority in disclosure. This has an interesting byproduct, namely that the systems of reputation in peer reviewed science are an effective signaling device, indicating to firms who might have the knowledge to help solve their particular problems (Dasgupta and David 1994). By contrast, the knowledge acquisition processes in business firms are to a degree closed, the general rule is to keep proprietary the results of research, either through secrecy or patent protection, and commercial prizes, while based on priority too, are not validated by rival producers but by the consumers in the market. Consequently, the open characteristics of science generally imply that it must be funded by public subvention, while the proprietary development of innovation is funded in the market process, ultimately by the consumers of the new products and the existing products

[12] An article in the Financial Times (29/11/07) by Jonathan Guthrie, "Business and boffins have a volatile chemistry", captures very well the difference between being an academic inventor and being an innovator, and the consequent need for arrangements to bridge between the two processes.

[13] On this later point, of the different tempo of academic and commercial life, see Cowan et al. 2008.

that are produced by new processes. In this context, the research intensive firm that conducts basic R&D is not an anomaly, as Rosenberg (1990) makes clear. It is intrinsic to our distinction between knowledge and information that the capacity to understand what others say does not come for free. Costly investments in the capacity to listen and comprehend are needed, and basic R&D is the route to creating the absorptive capacity to benefit from the research of outsiders to the firm.

The very different but complementary and creative roles of firms and universities lead to an obvious problem, "How is the inventive potential of the university to connect with the innovative potential of private firms?" Universities aid and abet the invention process but they cannot be natural loci of innovation, for that requires engagement with the market process and its different forms of organisation and governance (Rosenberg and Nelson 1993). Asking such questions about the role of the university is, however, not a new sport.

The Modern, Adaptive University

In 1963, Professor Clark Kerr, then President of the University of California, delivered the Godkin Lectures at Harvard on the theme "The Uses of the University" (Kerr 1967). He drew attention to long standing differences in the concept of a university that have existed at least since 1800.[14] One model is Cardinal Newman's liberal ivory tower (the Oxford model) with the humanities at its centre, the disinterested pursuit of truth its method, and the rounded intellect its product. A quite different model is contained in Von-Humboldt's vision (the Berlin model) in which philosophy and science form the core, with autonomous, specialised professors and their research groups as the method, and the valuable, useful, specialist the product. Behind these different meanings of the university lay a deeper issue encompassed by the utilitarian view of knowing, traceable to Francis Bacon, that universities have a duty and a purpose to further the welfare of human kind in whatever ways are practicable: the view which is fundamentally counterpoised to and inconsistent with the idea of the university as an ivory tower, the haven, as Leibnitz put it, of "monkish pursuits".[15]

The tensions created by the utilitarian view are reflected in the rise of engineering and other industrially oriented disciplines (chemistry for example) in the traditional universities in the nineteenth century, have been well documented by Guagnini (2004), tensions in relation to the search for academic status, and the demands made by laboratory based work on traditional financing and governance structures. One solution to the dilemmas implied was the creation of different models of technical

[14] Universities that were established from the end of the twelfth century onwards (Bologna, Paris, Oxford as exemplars) had strong ecclesiastical links and purposes, a bond that naturally began to weaken with the Renaissance and the rise of science and technology in the seventeenth century. See Ruegg (2004) for further essays on this theme.

[15] The complementary viewpoint espoused by Francis Bacon and others that the pre seventeenth century university was a scientific wilderness is effectively challenged by Porter (1996) in a carefully nuanced account of the interplay between the developments of science within and without the European universities of the time.

university or engineering school in France and Germany and subsequently in the UK, and the USA. Many of these engineering oriented universities developed leading capabilities in the knowledge underpinnings of particular technologies, Manchester (UK) in textiles, Dakron (Ohio) in rubber, Stanford (California) in aeronautics, Jena (Thuringia) in optics and glass, are examples that readily illustrate the theme. No one should doubt the close ties that have always bound industry and academy in the pursuit of technological advance. Nor should anyone doubt that the final responsibility for improving business performance through technical innovation lies with firms.

Not all commentators agree that universities should be tied to the real world in the way that they have been. Consider the American educationalist Flexner (1930), and his somewhat dystopian claim that universities should only be places for thinking and research and the training associated with research. His vision of the modern university left no room for vocational "training activities" (a false vision of a university and of its comparative advantage in an education system), in which category are included such disparate activities as teacher training, domestic science, journalism, optometry and business studies—he clearly did not approve of Harvard Business School![16] Echoes of this conflict are ever present, in the claim that universities should only perform curiosity oriented research, that mission oriented activity is not for them, that applied work can only drive out fundamental work. Such attempts to put artificial barriers between kinds of knowing are mischievous and often self serving: they deny Smith's combinatorial benefits, and they are countermanded by the facts of scientific discovery. It has always been the case that scientific knowledge is at the intersection of epistemic and practical interests and that the latter materially affect the discipline structure of knowledge: departments of computing or textile technology, or industrial chemistry or civil engineering, or cardiology or oncology are part and parcel of the life of many universities. Many able scientists, of whom Pasteur is a fine example, have found no conflict in focusing on particular fundamental problems because of their practical utility—a theme brilliantly explored by Stokes (1997).

There is one further dimension to note that is hinted at by Alfred Marshall, the English economist who was the last major economist to be concerned with knowledge and the division of labour, and for whom "knowledge aided by organisation" was the most powerful of the forces leading to economic growth. The nature of knowledge is that it leads to new knowledge and once this is reflected in formally organised research activities there is no knowing where it will lead. Isaiah Berlin captures the essential point: when writing of Vico and his understanding of history, we are told, "man is a self transforming creature, the satisfaction of each set of needs alters his character and breeds new needs and forms of life" he cannot therefore live his life "according to unvarying, timeless principles, for then there would be no growth, no historical change, only eternal repetition as in the lives of

[16] This is not to deny that the unworldly pursuit of abstract knowledge has potential practical benefits but it is the critical, scientific understanding of "industry, politics, law or medicine" (p. 342) that marks the contribution the university can make—their purpose is to educate not to train, to lay general purpose foundations not build specific structures. Rosenberg (1961) explores the relation between agricultural research and the growth of the American university system.

animals" (Berlin 2000, p. 65). The generation of new knowledge is not only a major source of economic transformation, it is also a major reason why the future is so unpredictable and uncertain. A society need not be organised to this end, as surviving indigenous societies illustrate (and they are knowledge based, too), but post Reformation and Renaissance the Western world stepped onto a different path with enormous gains in material welfare but no possible knowledge of what its future held.

This is not at all surprising when we recognise that the three great strands of technical advance that underpin our modern standard of living in relation to the production of goods and services are products of the discovery and harnessing of new forms of energy to displace human effort, the discovery of new materials in the environment and the synthesis of materials that have no natural existence. The growth of physics, chemistry and bioscience, and the multiple sub branches of the same, is of central importance on all fronts but so are the bridging sciences[17] and the net outcome has been the development of what Harvey and McMeekin (2007) term different, successive 'economies of knowledge', characterised not only by the production and use of finely divided and complementary bodies of understanding, but of emergent and complex modes of interaction between the public and private spheres of their production, dissemination and use, and of new instituted ways to manage the tensions between private appropriation and public placement. Three examples will serve to illustrate both the long standing nature of the interactions between private managers and public scientists and the very different forms of their mutual engagement across the business and university divide.

Murmann (2003) has carefully documented these interwoven strands in his account of the development of the German dyestuffs industry, either side of 1900. The lead that German universities had in teaching and research in fundamental chemistry and its instituting within an academic-industrial knowledge network was a material reason why major synthetic dye innovations occurred in German firms (and not in British or American firms). German firms could also expand on the basis of a ready supply of trained chemists to manage plants and conduct applied research in the new laboratories in the industry. German chemical firms willingly funded university research but other bridging processes were important too, particularly the growth of academic and industry chemical societies with joint or overlapping memberships in which, as Alfred Marshall put it, "the mysteries of the trade become no mysteries" and ideas are readily interchanged and, crucially, become "the source of further new ideas", a perfect Marshallian combination of restless knowledge and restless activity (1920, V, 10, 271).[18]

Sally Horrocks has also explored how a Department for Industrial Chemistry was established at the University of Liverpool in 1926 and followed a fundamental research programme in the chemistry of oils and fats that was of direct practical concern to major chemical and food processing firms in the region, one of these

[17] See Goldin and Katz (1999) for a broader account of the interplay between rapid industrial diversification and the diversification of university disciplines from the late 1980s onward.

[18] On the USA, see Mowery et al. (2001), on Europe, Murmann (2003); also Nelson (2004). As Murmann indicates, the British synthetic dye industry benefited from an influx of German chemists, while many of the business leaders in the German industry had spent time in the UK to familiarise themselves with the textile and traditional dyestuffs industries (*op cit*, pp. 71–74).

firms being Lever Bros. That company provided funds for project work and employed students who graduated from the department. However, as an indication of how the rational for a particular mode of interaction can change, that company became part of Unilever in 1929, and the merger and the subsequent refocusing of the R&D strategy and relocation of the research laboratories of the new company to the Netherlands and Germany served to break the ties with Liverpool University. Indeed, the Department in Liverpool was closed in the early 1950s, by which time its external support network had largely disappeared.[19]

To provide one final and very modern example among many, consider the compelling account by Harvey and McMeekin (2004, 2007) of the emergence of public and private interdependencies in the ongoing development of modern bioscience: centered around its three novel components of information, in the form of new databases, new tools of biological analysis, and new sequences of the genomes of specific organisms. They show that the sequencing of potentially the most globally significant biological organism (the fungus *Agrobacterium tumifaciens*) in 2001 was the result of an unplanned race between two separate business-academic collaborations, one centered on Monsanto and Hiram College, the other on Du Pont, the University of Washington and Campinas University in Brazil. The motives for business involvement proved to be complex and not simply reducible to a search for valuable intellectual property, and in both groups tensions arose from the different and changing strategic aims of the public and private partners. In each case, the business partners provided the capital intensive sequencing equipment while the academic partners provided the analysis and functional description of the resulting gene sequences, each playing to their comparative capabilities. The instituted relations of public science also played an important role: disclosure by one of the parties at a scientific conference resulted in simultaneous placement of the sequences in Genbank, while the journal *Nature* facilitated and encouraged the publication of their respective papers in the same issue to allocate priority to neither and thus to both the teams.[20]

These cases span more than a century but they are each an example of a particular division of labour in the production of new knowledge and the veracity of Smith's organising principle. In reflecting on their differences, it is useful to turn to Gibbons et al. (1994) who make a distinction between two modes of knowledge formation, modes that are complements not substitutes. In mode I, the traditional discipline oriented and organised research process in university departments looms

[19] See Horrocks (2007). Examples of this kind can be produced almost at will: military R&D needs have played a large role in this respect, but so have the links that market focused electrical and chemical companies thought it useful to develop with particular individual academic consultants and university-based research institutes. An excellent study of university industry interaction in the growth of the German optics industry is provided by Buenstorff and Murmann (2005). The medical supply industry provides many further, contemporary examples of the close intertwining of business and academia in the pursuit of innovation. See for example, Mina et al. (2007), and Metcalfe and Pickstone (2006).

[20] Harvey and McMeekin (2007) also discuss the sequencing of the fungus *Aspergillus niger* which was organised on very different lines, involving a Dutch biotechnology food company as lead partner, seventeen universities in five countries, and other commercial organisations and government funded laboratories. It is a fine example of the organising principle that epistemic collaborations are built around particular problem sequences that require multiple skills and capacities for their solution.

large, physics, chemistry and engineering are its exemplars. In these disciplines, clear methods exist for the verification of novel knowledge claims and the driving forces in the evolution of knowledge are the problem sequences that are cumulative and internal to the discipline. Broadly speaking, disciplines develop through their own internal logic and the respective practitioners are usually keenly aware of the boundaries which determine the limits to the content of that discipline and the rights to professional recognition within it. The productivity of this mode of organisation in terms of the growth of fundamental knowledge in science and engineering has been quite remarkable, a fact that scholars began to point to with increasing awe in the 1960s (Price and de Solla 1963). But there are many forms of knowledge that mankind lays claim to, and so it has always been the case that science is not the only category of knowing to be recognised as socially valuable, neither can we accept that the only reliable and useful knowledge is produced by its methods alone. Thus, the appearance of mode II knowledge, the process of production of which is characterised by four features: the synthesis of ideas from different disciplines; the overwhelming importance of the context of application in shaping the process of collaboration in knowledge production; the great diversity of the organisations that contribute to solving problems in this mode; and the increasing role of criteria external to science in determining the incentives to and assessment of the resulting outputs. Our three examples suggest a particular interpretation of this distinction. Namely that the two modes coexist and are complementary, and the fact that mode II has always existed, and surely predates mode I, should not cloud the importance of recognising their changing relative importance. This is particularly so in terms of current concerns about the role of universities in the innovation process and it is hardly surprising that this question should lie at the core of much contemporary thinking on the role of universities in wealth creation.

These debates reflect the inevitable fact that universities are not apart from the societies in which they exist, and that as a society and its knowledge base evolve, so does the university system embedded within it. Since any knowledge system cannot be separated from its associated economic system, so a university system cannot be separated from the economic system in which it is instituted. There is a deeper point of substance here. Knowledge develops in unforeseen ways, through processes that are evolutionary, cumulative and combinatorially rich in their immanent possibilities, such that knowledge cannot be contained or stabilised. Since universities play a major role in articulating this process and in stimulating possible adaptations in economy and society in response to new knowledge, they are also and inevitably required to adapt to what they create. If knowledge and economy are in a state of flux it is hardly possible for the universities to be isolated from that ceaseless movement. They must adapt to shifting balances, universities, above all other organisations, cannot be expected to stand apart, they are necessarily a reflection of the age.

Developing this theme, the first thing to note is that that the context for university business interaction in relation to innovation has changed greatly in the past three decades, perhaps more than in any other comparable period of recent history. A by no means complete list of pertinent developments would include: the general demise of centralised corporate, R&D laboratories in manufacturing industry, and the reorganisation of corporate, applied R&D around divisional, near to market activities; the increased internationalisation of R&D activity as some large firms become more willing to engage with universities on a world wide scale, even to the extent of locating their research facilities overseas to capitalise on local, low cost research excellence, especially in India and China; and the continued increase in the relative economic importance of "knowledge based service" activities, where the nature and meanings attached to "R&D activities" are quite different from those in manufacturing and other commodity producing sectors.

Taken together, these changes represent a fundamental restructuring of the context of university-business interaction in the innovation process. The changing mix of market and non-market actors, partly reflecting the decline of defense R&D, has greatly altered the scope for university-business interaction. To give just one example of the changing structure of innovation related activity, one may point to the rapid growth in the outsourcing of R&D by business; some recent estimates suggest that 15% of corporate R&D is outsourced, either as joint research projects or as research contracts to meet contractor needs (See Howells 1999).

It is remarkable how much innovation and structural adaptation the university system has experienced in the past four decades. If universities are not quite entrepreneurial, they are certainly remarkably adaptive. Within the constraints of public policy and limited funding, Western universities as a group as well as individually continue to evolve, lead and respond to the challenges and opportunities presented by the growth of knowledge. Consider, for example, the challenges created by the opening up of new branches of scientific and engineering knowledge (bioscience and medicine, software, new materials and nanotechnology, being prominent instances); the effects of a very rapid growth in the numbers of students enrolled; and the conundrums posed by a broadening range of commercial pressures and new models for public funding and accountability.

We are left with a dilemma, that of the university as a conservative institution operating in and drawing its resources from a dynamic environment. For the successful prosecution of its activities, the university needs internal stability, security and the continuity essential for the work of a body of scholars who are also inventors and explorers of ideas. How can that internal coherence be maintained in a world of multiple pressures and increasing concerns that universities become creators of wealth from knowledge? How is the internal mode of organisation to fit with the new demands of the external environment? What kind of bridges can be built? Is the division of labour between business and academy to be redrawn with the creation of new, as yet unspecified, organisational forms? A measure of the scale of these dilemmas is surely provided by the vigourous contemporary debates that address the tensions between collegial and managerial modes of functioning, between alternative modes of funding, between the free and open disclosure of research results and confidentiality in pursuit of IP ownership rights, and between appropriate modes of leadership and governance in organisations that have come to be judged by the services they provide to external clients as well as by the support they give to internal research, scholarship, teaching and the curation of information resources.[21] Thus, the mix of activities in a university, as reflected in its mix of faculty, students and course offerings, is continually changing, as is the changing pattern of the use of knowledge in society more widely.

To return to Kerr, he foresaw only too well the beginnings of these trends from his vantage point in the American system, and his conclusion was that the University is being displaced by the Multiversity, an organisation serving different communities (undergraduate, postgraduate, research, business and politics), that needs to be, as he put it, "as confused as possible for the sake of the preservation of the whole uneasy balance" (p. 18).

It is in this context that we can now draw together these different strands by considering the role of universities within innovation systems. Not least, this is a matter of controlling expectations, for it serves no purpose if universities are expected to play a role and be judged in ways which it is very difficult for them to perform well. Utilitarian views have their place but not when they are so narrowly construed as to be counterproductive.

"Only Connect" Universities in the Innovation System

In his novel, *Howards End*, E. M. Forster chose the epigraph "Only connect." to capture the difficulties of communicating between commercial and intellectual cultures in Edwardian Britain. These difficulties are of the essence in understanding the role of universities in national innovation processes.

We can see this most clearly by portraying universities and business firms as two of the component or actor elements in innovation ecosystems, reflecting the fact that while business firms are the ultimate transformers of ideas into commercial practice, their innovative efforts are not exclusively internal but depend upon access to external sources of information and the knowledge changing potential that they contain (Metcalfe 2007; Howells 2009). Innovation systems are forms of spontaneous order that are created and developed to solve problems which arise in the innovation process, and as these problems change, so do the forms of the particular innovation systems in terms of the actors, connections and boundaries. While they are naturally shaped by the national contexts of instituted rules within which universities and business firms operate, they are necessarily defined in practice at a much lower level, that of the particular innovation problem sequence, and at a higher level, in that the respective actors may be located in different countries. This is hardly surprising, market processes are overwhelmingly international in the modern economy and science has always operated on the basis of international engagement.

Much has been written in recent times on the concept of innovation systems, but it is also noteworthy that Alfred Marshall, in his *Industry and Trade* (1919), sketched the main features of what we would now call an innovation system by distinguishing different kinds of research organisation, universities, technology intensive firms and private consultancies and other knowledge intensive intermediary service providers, each type fulfilling a different role in an economy's

[21] See Observatory of the European University (OEU) 2007, 'Position Paper', PRIME Network.

knowledge ecology.[22] As with any division of labour, the functioning of the resulting system depends on how the specialised components are interconnected, in this case not by arms-length anonymous market transactions but by personal scientific contacts and common reference to published bodies of highly codified information. Thus, Marshall explains, the technical research laboratory of an industry benefits from keeping in touch with the chief scientific laboratories, and "the latter may gain much and lose nothing" by keeping in touch with the industries whose methods may be improved by the fruits of fundamental research. Marshall's thoroughly modern account of the innovation processes therefore is one in which advances in knowledge are made by different actors, having differentiated capabilities and specialisations, working in different kinds of organisation with different motives and distinctive methods. However, it works to the degree that the component elements interact and connect. What Marshall does not tell us is how this diversity of objectives and modes of functioning, funding and organisation, may encourage or inhibit the coordination process, the problem that so concerns policymakers world wide.

One obvious coordination process that motivates the connections and relations within an innovation system is the flow of information between the specialised actors. If the transfer of knowledge from universities to business could be fully and efficiently achieved through placing knowledge in the public domain there would be little need to consider the matter further. Because university researchers have strong incentives to publish their findings, such information is readily accessible to firms; the managers of commercial innovation projects need only "read the relevant literature and connect". Publications are indeed an important source of innovation related ideas but the issues are far more subtle. Not all of the knowledge possessed by scientists is placed in the public domain, and the unexpressed (tacit) components of knowledge matter critically in translating a generic scientific discovery or technological result into a specific, commercially viable application. Fundamental knowledge is too abstract in many cases to map easily onto practical problems in firms, and a translational or developmental gap usually needs to be bridged.[23] Here, there is a matter of some substance. The knowledge output of universities is certainly a public good, in the sense that using it does not consume it, but this in no sense implies that it is freely accessible to any individual. Only those who have made the requisite investments in their own understanding of the relevant fields can expect to translate new information into new personal knowledge. The implication is clear, firms need to invest in absorptive capacity if they are to pose the relevant questions and recognise the relevant answers, and this absorptive capacity is largely based on the employment of qualified scientists and technologists, certainly in R&D activities but also in more operational positions within the organisation (Carter and Williams 1957). A firm must invest in the absorptive capacity to know what

[22] Today we would include in the latter category the metrology laboratories and public or quasi-public "standards institutes" charged with setting and disseminating physical and technical standards, and checking compliance of products with specifications mandated by government regulations. On the general classification and role of innovation intermediaries, see Howells (2006).

[23] A referee usefully suggested that this problem be thought of in terms of a gap between proof of concept and commercial realisation.

questions to ask, and who to address them to, and how to interpret the answers in the resolution of its innovation problems.[24] Proctor and Gamble are a well known example on both counts. They have articulated the view that for every scientist and engineer in-house there are 200 scientists and engineers of equal quality outside the firm—a total of 1.5 million skilled individuals who they could use to facilitate their innovation programmes. Indeed it expresses the ambition that half of its innovations should originate from external sources rather than in-house programmes. Not all companies grasp the point, nor should we expect them to.

Thus, Marshall was pointing to two important facts about this sophisticated and uneven division of labour. First, that few firms can manage to innovate entirely through their own internal efforts, and secondly, that access to external knowledge requires that the firm develop an external organisation to complement its internal arrangements. Here, there is a considerable shift of focus away from problems of incentives to innovate and the resources devoted to innovation, the traditional basis for R&D policy subsidies, towards questions of the perception of innovation opportunities and the capacity to manage the innovation process. These are intrinsically systemic questions. Let us explore them in more detail.

Consider first the boundary problem, one instantiation of which is the degree to which a firm seeks to develop all its innovation related knowledge in-house. This it can do but the fact that innovation can require support from multiple disciplinary bases makes it unlikely that all but the largest firms with extensive R&D facilities can follow this route. For many firms their innovative efforts would be strengthened and focused more effectively by access to external sources of knowledge. The appropriate boundary to the firm must so be drawn as to reflect the economies that accrue from drawing upon external sources of information, which is nothing more than a generalisation of Coase's (1937) dictum that the boundary of the firm reflects the relative costs of internal and external sourcing different kinds of productive inputs. As we have already suggested, while the costs of transmitting information can be low, the ability to learn from that information is contingent on a capital investment in absorptive capacity. Moreover, the discovery of where the necessary information lies imposes its own costs which may be summed up in the idea that the firm must invest in its own external organisation if it is to benefit from external knowledge economies. Since these costs are largely of the form of a fixed cost they will bear unequally on firms of different sizes and provide a bias against the smaller firm that wants to join an innovation system. All of this points to the very uneven engagement of different firms in the process of innovation system formation, in large part contingent on their individual stances towards innovation as a basis for commercial advantage.

The boundary problems of universities are of a very different kind. They are naturally open, collaborative organisations when it comes to the pursuit of scientific knowledge, they are naturally international in outlook, natural participants in the systems of science but they do not naturally look to business firms for assistance in

[24] Rosenberg (1990) is one classic reference in a large literature on absorptive capacity. A recent review by Agrawal (2001) is a useful starting point for the interested reader. See also Perkmann and Walsh (2007).

the solution of scientific problems. Nonetheless, even when portrayed as disinterested producers of scientifically verifiable knowledge, universities have an impressive record as contributors to the process of innovation, in terms of the development of concepts, theories and instrumental procedures or through the supply of educated students available for employment in business and other walks of life. The chemical industry, the computer industry and the internet industries around it, and the pharmaceutical and medical supply industries are monuments to the value of practical knowledge that engages with fundamental work in universities.

This brings us to the crucial question of connectivity, for it is the connections and relational interactions that translate the ecology of innovation actors into a particular innovation system. Connections between firms and universities are the outcome of spontaneous ordering processes, and do not depend on universities taking any direct interest in innovation or wealth creation or firms taking any interest in the accumulation of scientific knowledge, although they may. They arise only to the extent that collaboration in the innovation process is of benefit to both parties and the possible means of interaction between firms and universities are, therefore, many and varied. Some of these processes are indirect and anonymous, as reflected in the operation of the markets for graduate employment, or in the access which any firm has in principle to published scientific literature or access to scientific conferences. Other processes are direct and personal, as with consultancy services, research contracts or collaborative research programmes and depend for their operation on matters of trust and personal engagement, matters at the core of network formation processes.[25]

Survey evidence adds strong support to the self organisation theme. Alan Hughes and his colleagues in Cambridge have done important work here, drawing upon detailed surveys of practice in the USA and UK (Cosh et al. 2006; Hughes 2007; Cosh and Hughes 2008). They show that universities contribute to innovation performance in many subtle ways: most obviously through the supply of the trained minds of graduate employees, through research contracts, through the purchase of licenses, and through consultancy arrangements; and, least obviously but very importantly, by being a public space for the organisation of conferences, for the conduct of professional scientific networks, and for a plethora of other routes to social interaction including periods of secondment between academy and industry. When asked to rank the relative importance of different kinds of connection in the

[25] Abrue et al. (2008) provide many examples of different modes of connectivity in the UK system, ranging from joint research laboratories set up by a company and different university partners (the Rolls Royce model and the BP institute model), to general cooperative framework agreements between a firm and a university department (Waitrose and Lancaster University), and to firms providing projects to serve as the basis for a Ph.D. (Electronic Arts and UCL). That there is so much diversity in the modes of interaction is exactly what one would expect of a complex adaptive process, in which novel modes of interaction are proposed and tested continually. Many fail, one might imagine, but others become part of a transforming spontaneous order. D'Este and Patel (2007) provide detailed evidence on the different modes of interaction and the factors influencing the propensity of research grant holders to engage with business firms in the UK. Link et al. (2007), provide evidence for US universities on the propensity to engage in informal collaboration. Further examples of the wide range of connection modes may be found in Kitson et al. (2009).

innovation process, the firms responded that it was informal contacts, recruitment of students, publications and conferences that contributed most to innovative efforts, while licensing, research projects in universities and consultancies are numerically far less important in contributing to the innovative efforts of firms. Exclusive and non-exclusive licensing were the least significant of the contributing interactions (Cosh et al. 2006).

Claims for the self organising structure of innovation processes finds further corroboration when firms are asked to specify the source of the ideas that help solve innovation related problems. Table 1 shows the outcome and we immediately see the relative unimportance in both countries of universities and other research laboratories, whether public or private. As the table shows, it is the internal efforts of firms that provide the most important source of ideas but external factors unconnected to universities are important, too. The connections that are market process-mediated, links with customers and suppliers and indeed competitors, are far more important to firm's innovative activities than are their links with the wider research system. This is as one might predict. Innovation is not simply invention, it is a commercialisation process and since that is embedded in market relations, it is hardly surprising that links with customers and suppliers and even competitors are

Table 1 Importance of sources of knowledge (% of users of that source)

	UK %	US %	Ratio (UK/US) × 100
Company sector			
Suppliers of equipment, materials, components, or software	41.5	49.2	84.4
Internal knowledge within the company	79.9	84.5	94.6
Clients or customers	60.9	53.5	113.7
Knowledge within the group	59.4	50.7	117.1
Competitors in your line of business	27.7	20.8	132.9
Intermediating and regulatory organisations			
Consultants	12.5	26.2	47.7
Professional conferences, meetings	14.6	23.9	61.2
Trade associations	15.1	23.5	64.4
Technical/trade press, computer databases	21.5	26.5	80.8
Fairs, exhibitions	17.4	18.0	96.8
Environmental standards and regulations	31.8	46.1	69.0
Technical standards or standard setting bodies	34.6	40.2	86.1
Health and safety standards and regulations	41.3	47.2	87.5
Other public sector, e.g., business links, government offices	10.5	38.7	27.1
Scientific knowledge base			
Government research organisations	6.6	24.7	26.6
Private research institutes	7.2	22.9	31.5
Commercial laboratories or R&D enterprises	12.2	28.4	43.0
Universities/higher education institutes	13.8	27.0	51.3

Source Cosh and Hughes (2008)

of dominant importance or that ‘standards and regulations’ should figure as significant stimuli to innovation.

But there are difficulties in drawing too robust a conclusion from this data, in so far as we ought to distinguish direct and indirect linkages between firms and universities. The table makes clear that the way knowledge is conveyed to firms also depends on the existence of innovation intermediaries, those specialised knowledge organisations that bridge between universities and firms. Thus, it is possible that the connections can be indirect, through an innovation supply chain, and would not necessarily be registered as university linkages. In Table 1, the intermediaries are typically consultancy firms or specialised research laboratories (some of which are privatised former public research laboratories or industry research associations) that have accumulated expertise in transfer sciences and the industrial technologies into which they feed (Howells 2006). It is precisely because information does not flow easily between unlike minds that such agents are able to play important (and profitable) roles in innovative activities. Variously called bridging organisations, technology brokers or boundary organisations, they serve not only to connect different components of innovation systems in responsive mode, but also to perform pro-actively, by animating new connections that might not otherwise arise spontaneously. More recent work (Tether and Tajar 2008) shows that consultancy based intermediaries are particularly important to the innovating efforts of service firms. Nor should one forget the complementary role of the specialised technical and trade press in diffusing information in the innovation process, one of Marshall’s important sources of external economy. Thus, a fuller picture depends on a deeper understanding of the connections between innovation intermediaries and universities.[26]

These findings suggest the need for a considerable reorientation in our understanding of how universities contribute to the process of wealth creation. Universities are important players in innovation systems but the modes of their influence are diffuse and general as well as focused and specific. Nowhere is this need for a reorientation more pressing than in respect of the role of licensing and technology transfer as modes of connection within innovation systems. The survey evidence is clear, they play a role but it is very much the minor role in the innovation process. Moreover, the extreme uncertainty of and the skewed value of patents means that out of the total patent flow very few amount to a significant commercial prospect, and universities would be very unwise to treat license income as a durable revenue scheme.[27]

The recent encouragement of the patenting of university developed inventions, and their exploitation either directly in campus spin-off companies or indirectly through licenses or equity stakes in third parties, also provides a useful reminder of the unintended consequences of policies that can damage the natural, long

[26] To suggest one example of a potentially significant intermediate linkage, we might consider the role of universities in shaping standards and regulation, which, as Table 1 shows, are a significant direct influence on the innovative activities of firms.

[27] Of a total income of circa £2bn earned by UK universities from the business sector in 2006/7, only 2% was IP related. The balance was accounted for as follows, 57% from contract and collaborative research, 32% from consultancy and continuous professional development and 9% from regeneration activities. Figures quoted from Kitson et al. (2009).

established spontaneous channels of business-university connection.[28] There is a real danger that an over zealous concern with "market-driven" technology transfers creates impediments to inter-organisational collaboration, and, at very least, tends to inhibit the scope for universities to develop more frequent inter-personal collaborative contacts and to encourage exchange of scientific and technological information with business. In short, it may prove to be too easy to design rules that inhibit the progress of a spontaneous order formation by privileging transactions rather than relationships, to the long term detriment of the wealth creation process.[29] All of this points to the dangers of simple minded views of the role of universities in the innovation process. To paraphrase Verspagen (2006), far more knowledge has been flowing between universities and business firms than the concern with university patents and licenses would suggest.[30]

This is not to downplay barriers to connection and system emergence or the formulation of policies that reduce the costs of connection.[31] The natural desire for commercial confidentiality in a firm does not fit easily with the rules of open science in the university system, indeed some authors have expressed deep concerns that too close a degree of interaction between universities and firms can undermine the nature of academic endeavour and subvert the public commons character of university research (Nelson 2004). On the other hand, conflicts of a public versus private nature can be shaped and accommodated by the emergence of new instituted rules of the game, as Harvey and McMeekin (2007) demonstrate for the new biosciences. On the university side, the organisational context in which their faculty work and the structure of the institutionalised incentives and constraints are crucial to their connectivity with other agents and the productivity of their activities (Foray 2004; Link et al. 2007), and act as powerful shapers of their propensity to interact across the research system in general and with business firms in particular. Nor should the opportunity costs of business-university engagement be forgotten, time is always a scarce resource. There is no single best way to improve on connectivity and a wise policy will set general rules and foster many experiments exploring the merits of different approaches. In respect of any spontaneous order good policies are emergent and the outcome of variation cum selection processes. More

[28] Over the period 2000–2007 the number of UK licensing agreements grew by 350% while licence revenue increased by 220%, signifying a drop in the average income per licence of 25%. Full time staff in technology transfer offices grew in the same period from 1,538 to 7,440. The number of university spin outs seemed to be without trend (source HEFC-Business Community Interaction data).

[29] One harbinger of the growing unease of the business community with these developments may be inferred from the recently announced Open Collaborative Research Program, under which I.B.M., Hewlett-Packard, Intel, and Cisco Systems together with seven US universities have agreed to embark on a series of collaborative software research undertakings in areas such as privacy, security and medical decision making. The intriguing feature of the agreement is the parties' commitment to make their research results freely and publicly available. Their avowed purpose in this is to able to begin cooperative work, by freeing themselves from the lengthy delays and costly, frustrating negotiations over IP rights that proposals for such collaborative projects typically encounter.

[30] The difficulties in establishing the extent of university involvement in the patenting process are laid bare in Geuna and Nesta (2006).

[31] One might also add that the internal division of labour between academic researchers and technology transfer offices may create its own barriers to connectivity, as a referee pointed out.

fundamentally, they develop social technologies that reflect a shift in the balance of innovation policy away from allocating resources to R&D towards enhancing awareness of the opportunities for innovation and improving the management of the external innovative organisation of firms.

Our focus on the connection problem should not be taken to imply that this is the only important aspect of policy in relation to innovation and the production of public and private knowledge. Connections require individuals to be connected, and so there is a natural policy concern with what we might term an economy's knowledge ecology, those knowledgeable individuals (their specialised knowledge and their organisational contexts) who are ready to contribute to the identification and solution of innovation problems. Does a nation support appropriate kinds of scientific research and the associated scientists? Is the disciplinary balance of funding right? How easy is it for new disciplines and combinations of disciplines to emerge? Do research groups exist that are at the forefront of international research? Here, the evolutionary systems perspective has a particular contribution to make in terms of the design of open frameworks which permit the spontaneous evolution of the ecology by processes of expert scientific and technological judgment. As Polanyi (1962) emphasised, these are not matters of central planning but of the organisation of distributed decision making processes that draw on the expertise of the appropriately knowledgeable communities. Nor are these matters that can be fruitfully thought of in terms of optimal resource allocation, rather they require a conceptual frame that works in terms of adaptation to emergent opportunities. While government may rightly set the overall volume of resources devoted to public knowledge acquisition, it also has a responsibility to ensure that the processes of allocation to scientific research programmes and projects are open to the emergent possibilities inherent to the growth of knowledge. In part this is achieved by the scientific community itself and its role within the framework of scientific advice for budget allocation, the Polanyi principle, but it is also achieved by ensuring that the allocation procedures engage with the business community, and there is a very clear reason for this. The organisation of science is predominantly discipline-based but the problems of innovation are typically multidisciplinary, their solution is in the nature of a connected research programme not an isolated research project. A discipline focus is likely, therefore, to miss important knowledge synergies and complementarities and to put barriers in the way of emerging areas of scientific advance. A wise policy will ensure that the pattern of advice is plural in nature, that it is designed to keep the system open to new possibilities. This is not a question of choosing between fundamental or applied research, as is often claimed, but rather it is a question of filling Pasteur's quadrant with fundamental research which engages with innovation problems, and which, in turn, becomes the stimulus to the development of further bridging research.

Conclusion

Our argument has followed directly from the distinction between designed and spontaneous orders and their connection with the division of labour. We have suggested that innovation systems are examples of spontaneous order formation shaped by the particular rules of the game within which firms and universities operate. We have argued for the transience of university-industry relations around particular problem sequences, and that such relations are the emergent properties of subtle processes that have for long been in operation. That they may be improved upon is self evident but one should not presume that perceived problems in system formation are the consequence of the behaviour of one of the parties. Whether or not that functional "systemic property" is emergent, should not be viewed as determined only by the characteristics and performance qualities of universities alone but by the wider set of organisations in any innovation system.[32]

We might reasonably conclude that university-industry interactions are a normal part of the innovative process, that they arise spontaneously, that they form and reform unpredictably over time to address many different kinds of problems, and that the forms of connection are of many different kinds. This elaborate division of labour has worked well but its continued functioning depends on two crucial factors: the ability of the universities to maintain an open perspective in the face of resource and governance pressures; and the willingness of firms to invest in innovation and develop the absorptive capacity to engage with the science base in academia.

Critics of the role of universities and firms in respect to their performance in supporting wealth creation should reflect first on the fact that the division of labour between profit seeking business corporations and universities reflects both the quite distinct roles that these organisations fulfill, and, the complementarity between those roles. We can all understand that it would be as unwise to expect firms to behave like universities as it would be to expect universities to behave like firms. The division of labour is there for a purpose, it should be respected.[33]

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[32] David and Metcalfe (2008).

[33] Requiring universities to switch their efforts towards applied R&D would be one example of the argument for not respecting the division of labour. It is not uncommon to find R&D directors of major research intensive firms who are uniformly opposed to such a development, precisely on the grounds of the comparative advantage of universities in basic research and of firms in applied research and development. See also, Kaufmann and Todtling (2001).

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